原著論文

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Prevention and Reduction of Earthquake Disasters in Asia and the Pacific Region

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抄録：地震は過去25年間で世界から1千万人以上の人命を奪った。とりわけ，アジア・太平洋地域の中国・日本・イラン・インド・パキスタン・アフガニスタン・トルコでは地震による被害が甚大である。これら地震多発国は地震を引き起こすプレート活動の活発な地域に位置している。地震波は自然災害であるので止めることは出来ないが，適切な防御策を講じることで被害を小さくすることができる。この防御策には，地震多発国の過去の地震災害の研究，危機アセスメントの準備，地震に弱い地域を示したハザードマップ，適切な建築基準の履行が必要である

キーワード：地震，アジア，プレートテクトニクス，防災

Abstract：Earthquakes have killed more than one million people during the past 25 years worldwide, and in Asia and the Pacific region, China, Japan, Iran, India, Pakistan, Afghanistan and Turkey suffered too much due to earthquake disasters. These earthquake-prone countries are situated in regions where plate tectonic activity is still going on to generate earthquakes. Earthquakes are natural hazards, which cannot be stopped but the hazards can be prevented from becoming disasters by taking appropriate preventive measures. These preventive measures include a complete analysis of the earthquake-prone areas for the past disaster events, preparation of risk assessment and hazard maps to delineate areas vulnerable to earthquakes and adopting and implementing appropriate building codes.

Keywords：Earthquake, Asia, Plate tectonic, Disaster, Prevention

Ⅰ. Introduction

Earthquakes are always sudden and the most destructive natural disasters in terms of life and property losses. In a global survey covering the period 1970-1997 prepared by the Swiss Reassurance Company, published in 1998, of the 40 worst catastrophes, which caused over a million deaths, 48% were due the earthquakes. The Asian and Pacific region countries received 75% catastrophes (IDNDR-ESCAP 1999).

Some earthquakes have unforgettable history in terms of devastations, e.g., the 1976 Tangshan China earthquake killed over 240,000 people; the 1923 Great Kanto earthquake killed 140,000 people; the 17 January 1995 Hanshin-Awaji earthquake killed 5,502 people and injured 41,500, and causing damage worth over US$ 100 billion, equivalent to 0.8% of the GNP; the 1964 Alaskan earthquake caused millions of dollars damage (Plafker 1964; Chen et al., 1976; IDNDR-ESCAP 1999; Balassanian 2002).

Earthquakes in Turkey, India and Iran killed over 250,000 people and rendered thousands homeless in 1999, 2001 and 2003. The December 2003 earthquake in Iran destroyed the historic city of Bam. The year 2004 also witnessed earthquakes in Morocco and Turkey in which about 3,000 people were died and thousands injured.

The main reasons for these deaths and property losses during earthquakes are the continuous increase in population, and the increase in building density without proper planning. It is very unfortunate that majority of the people of this region are unaware that they are sitting on tectonic plates which try to move past each other, and during this process to produce earthquakes at the margin or edges of these tectonic plates.

Ⅱ. Objectives

The main objectives of this manuscript are:

1. To highlight earthquake disasters in Asia and the Pacific region.

2. To prevent and reduce the earthquake disasters
3. To prepare and respond to the earthquake disasters

Ⅲ. How earthquakes are produced?

Earthquakes are produced due the Earth's plate tectonic movement. The Earth's crust is composed of a number of rigid and heterogeneous plates, called tectonic plates, which move very slowly on top of a weaker homogeneous layer (asthenosphere) within the Earth. When two plates collide or slide past each other, pressure builds up within the Earth's crust. Earthquakes occur when pressure within the Earth's crust increases slowly with times and finally exceeds the strength of the rocks.

Earthquakes may also be associated with volcanic activity and sometimes with landslides and explosions. Through out the world, earthquakes occur at a rate of several hundred per day. A worldwide network of seismographs detects about one million small earthquakes per year. The destruction of an earthquake depends upon its magnitude and duration, or the amount of shaking. There are some common earthquake terms, which need to be described as under.

1. Focus and Epicentre

Focus is the point within the Earth along the rupturing geological fault where an earthquake originates (Fig. 1). The epicentre is the place on the surface of the earth under which an earthquake rupture originates, often given in degrees of latitude (north-south) and longitude (east-west). The epicentre lies directly above the focus. Professor Don Gendzwill, University of Saskatchewan, Canada classified earthquake depths into, i) shallow: 0km to 70km, ii) intermediate: 70km to 300km and iii) deep: 300km to 700km

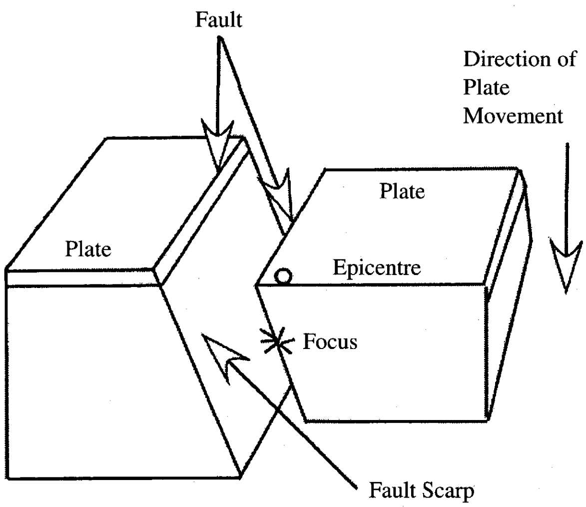

Fig 1. Block diagram showing epicenter and focus (hypocenter) of a fault.

The great majority of earthquakes are shallow, with focal depth less than 30 km below the surface, where rocks are relatively cold and brittle.

2. Faults

A fault is a fracture or zone of fractures in a rock along which there has been displacement of the sides relative to one another. There are three main types of faults. The surface between the two sides of a fault lies in a plane, and the direction of the plane is usually not vertical; rather dips at an angle into the earth. When the rock hanging over the dipping fault plane slips downward into the ground, the fault is called normal fault. When the hanging wall slips upward in relation to the footwall, the fault is called reverse fault. When both sides of a rock slide past each along a fault plane, it is called the strike-slip fault

3. Waves

The sudden movement of rocks along a fault causes vibrations that transmit energy through the earth in the form of waves. Waves that travel in the rocks below the surface of the Earth are called body waves: primary, or P-waves, which are very fast. The other type of waves is secondary, or S-waves. The S- waves also known as shearing waves, which move the ground back and forth, are very fatal.

Ⅳ. Earthquake hazards in Asia and the Pacific region

Earthquakes have caused more than one million deaths worldwide during the past 25 years. About 70 % of the earthquakes measuring seven or over on the Richter scale occurred in the Asian and Pacific region at an average rate of 15 per year. For example the 20th June 1990 earthquake in the northern part of Iran claimed 36,000 lives largely because of the collapse of dwellings made of material, which were non-resistant to earthquakes. The earthquake of May 1997 in Northern Iran killed over 1,500 people, injuring 2,300 and left homeless about 50,000 people. The earthquake of 26th December 2003 in Iran destroyed the historic city of Bam killing more than 40,000 people and injuring more than 30,000 (Eshghi and Zare, 2003).

The earthquake of February 1991 in Afghanistan claimed 545 lives. Again in May 1994, the northern part of Afghanistan experienced an earthquake causing 160 deaths with 20,000 houses and 260 public buildings damaged or destroyed. The event of April 1998 in Afghanistan was the most destructive so far in which 8,000 people died (Ambraseys and Bilham, 2003).

In May and August 1992, two powerful earthquakes struck a remote and mountainous part of Kyrgyzstan, destroying 11,000 houses and damaging more than 18,000 others. Like Iran, in Afghanistan and Kyrgyzstan, the houses could not withstand earthquakes, therefore, caused such a large-scale damage. In Kazakhstan, during the 1992-1993 period three earthquakes were felt which killed two persons and caused a total damage of US$ 1 million. About 450,000 km^2 of Kazakh territory in the South and Southeast, with a total population of 6 million, is located in a region of high seismicity (Balassanian 2002).

Seismic risk map shows that India is highly vulnerable for earthquake hazards. India has witnessed more than 650 earthquakes of magnitude >5 during the last hundred year that shows that earthquakes increased alarmingly here. The June 12, 1897 earthquake of the Shillong Plateau is one of the greatest events. Casualty was only 1,542 compared to the magnitude of the event (8.7). All concrete structures within an area of 50,000 km^2 were destroyed. The 1905 Kangra earthquake killed 20,000 people in the Himalayan region of India. On 26 January 2001, a violent earthquake of magnitude 7.6 on Richter scale rocked Bhuj area of Gujarat killing 13,805 people and injuring 167,000. This earthquake was the largest to strike India in 50 years (IDNDR-ESCAP 1999).

In Nepal, every year, thousands of various sizes of earthquakes occur (magnitude usually between 2 and 5, sometimes more). However, this important seismicity is far from being able to release the accumulated energy in the rocks of the crust by the northward movement of the Indian plate. However, the western and central Nepal seems to be the main risk area for the occurrence of the next large and destructive earthquake in Himalaya.

Pakistan lies in an active plate tectonic regime. The Chaman strike slip fault system was responsible for a powerful earthquake that destroyed Quetta, the capital city of Balochistan and the adjoining areas on 31 May 1935 (Zaigham 2001). More than 35,000 people were killed and according to Khan et al. (2002) more than 60,000 people were killed; most of those fatalities were in Quetta city. Tremors were felt over much of Pakistan and as far as Agra in India. Based on geometric seismic moment, the moment magnitude of this earthquake was estimated at 7.7

The Geological Survey of Pakistan has published the seismic risk map of the country. Based on expected ground acceleration, the country has been divided into 4 seismic risk zones. The areas surrounding Quetta, along the Makran coast and parts of the NWFP, along the Afghan border fall in Zone IV. Major cities of Pakistan namely Peshawar, Rawalpindi and Islamabad sit in Zone II. According to Global Seismic Hazard Assessment Programme (GSHAP), the most vulnerable parts of Pakistan are parts of Balochistan province in and around Quetta stretching to the Afghanistan border and western parts of Balochistan, which include the Makran coast up to the Iranian border. These regions could expect to have maximum peak ground acceleration (PGA) ranging between 0.24g and 0.4g.

Japan represents an extremely active area of subduction in terms of plate tectonics. In northeast Japan, the Pacific plate is subducting with a rapid convergence rate of 91mm/year, forming the Japan Trench (Uyeda 1991). Off the coast of southwestern Japan, the Pacific plate is subducting under the Philippines Sea plate, which in turn is subducting under the Eurasian plate, forming the Nankai Trough. The convergence rate between the Philippine Sea plate and the Eurasian plate is estimated at 45 mm/year.

The subduction seismicity varies greatly in Japan. In northeast Japan, seismicity extends to greater depths compared with southwest Japan. The dataset from the Japan Meteorological Agency for the period of 1994-2000 contains nearly 400,000 earthquakes recorded at 1012 stations.

On the September 1, 1923, an earthquake of magnitude 8.3 occurred near the densely populated, industrial cities of Tokyo and Yokohama, Japan (Toda et al., 1998). The epicenter was placed in Sagami Bay just southwest of Tokyo Bay. Destruction ranged from far up into the Hakone mountains, home to popular tourist resorts, to the busy shipping lanes of Yokohama Bay, north to the city of Tokyo. Tokyo's business and industrial districts lay in ruins. Deaths were estimated at nearly 100,000 with an additional 40,000 missing. Hundreds of thousands were left homeless in the resulting fires. Fires in the Honjo and Fukagawa districts of Tokyo surrounded over 30,000 people who took refuge in a large open area.

The 17 January 1995 earthquake of 7.2 on Richter scale shocked the Kobe-Osaka region, one of the most densely populated areas in Japan, taking nearly 5,500 lives, injuring 37,000 and totally or severely destroying over 200,000 houses and causing a total damage of at least US$ 100 billion.

China has been suffering heavily from earthquakes. It has been estimated that since the beginning of this century, earthquakes in China claimed over 600,000 lives, accounting for 50 % of the global total for this period. From 1949 to 1999, earthquakes killed nearly 300,000 people in China, injured and disabled over 800,000 and damaged over 12 million housing units and caused direct economic losses of billions of dollars. The February 1996 earthquake in Yunnan province killed over 320 persons and destroyed or damaged one million dwellings. In China, four fifths of its territorial area, 60 % of large cities and 70 % of mega-cities are located in seismic zones. In terms of magnitude, the western part of China is liable to be struck by stronger earthquakes than those striking the eastern part. However, the casualties and economic losses caused by earthquakes to the East, where the population and economic activities are concentrated, are higher than in the western part of China.

Thailand experienced some tremors causing slight damage, mostly in the western and northern areas. The epicentre of the earthquake was located near the northern borders. Similarly, the Lao People's Democratic Republic and Viet Nam experience some earthquakes as well.

In Viet Nam, the Red River Delta is the country's most seismically active area. Lying on a major geological fault, it has been shaken by 500-recorded earthquakes. The capital city of Hanoi, and nearly half of the total population of the country live here and more and more people are moving in (IDNDR-ESCAP 1999).

The Philippines lies between two of the world's major tectonic plates and experiences an average of five earthquakes a day, most of which are imperceptible. The earthquake on 16 July 1990 was one of the strongest and most destructive to have occurred in the country recently. The tremor had a magnitude of 7.7 on the Richter scale and affected an area of about 100,000 km^2 on the island of Luzon. Liquefaction of water saturated sediments caused extensive damage to coastal areas. Tremors destroyed or damaged a large number of buildings. As a whole, the earthquake killed 1,666 people, injured 3,561, and caused a total damage of nearly US $1 billion.

According to (IDNDR-ESCAP 1999) Indonesia is also vulnerable to earthquakes. On 12 December 1992, an earthquake with a magnitude of 7.5 Richter scale occurred, followed by tsunamis, affecting mainly the Flores Island. About 2,000 people were killed and 90,000 rendered homeless. Another earthquake of 6.5 Richter scale shook the southern part of Sumatra Island on 16 February 1994, which was also felt in Jakarta, killing 270 people and injuring 464. In this earthquake over 2,000 houses, 133 government buildings, 138 schools and 184 mosques were damaged. The total damage was estimated as US$ 170 million. On 2 June 1994, an earthquake occurred south of Java that created tsunamis killing 222 people, injuring 440, destroying over 1,350 houses and damaged 768 fishing boats. The earthquake of February 1996 in Indonesia killed more than 100 persons and destroyed over 5,000 houses.

V. Prevention and preparedness for the earthquake disasters

It is a universal fact that hazards hamper socio-economic development of a nation. Therefore, sustainable efforts are needed to prevent and mitigate such hazards. In this regard the General Assembly of the United Nations designated the 1990s as the International Decade for Natural Disaster Reduction (IDNDR).

The prediction of earthquakes is rather difficult but even if such prediction is made, the people get little time to move to safer places. However, necessary arrangements can be initiated to cope with such disasters. For example: to analyze the disaster-prone areas for the past disaster events, the socio-economic conditions of the people living in the area, and major structures of public concern and to assess the risk and to prepare hazard maps that would delineate areas vulnerable to earthquake disasters.

As a preventive measure, earthquake-resistant designs for dwellings have helped to reduce the number of casualties and prevent serious damage to buildings. For example in the Kobe earthquake, those buildings sustained little damage, which were built after 1981. Mitigation measures are required to improve the safety of non-engineered structures such as ordinary dwellings and simple public buildings constructed with local materials in the traditional manner.

Besides Japan, many other countries have adopted appropriate building design codes that reduced life and the property losses but in parts of the region there is still a need to prepare and revise earthquake resistant design codes for buildings and other engineering structures and for their enforcement, as well as the undertaking of proper arrangements for the infrastructure to be able to deal with earthquake disasters. As an utmost requirement, many countries have made laws, which provide the necessary controls and responsibilities to deal with disaster situations. These laws permit the relevant authorities to govern the long-term requirements of disaster prevention and the short-term needs of disaster preparedness ((IDNDR-ESCAP 1999).

The following paragraphs highlight efforts initiated by the earthquake-prone countries.

1. China

Earthquakes are the main natural hazards in China, prompting both structural and non-structural measures for natural disaster reduction (IDNDR-ESCAP 1999). The Chinese National Committee for IDNDR has been responsible for inter-departmental coordination of 28 ministries, commissions and administrations since its establishment in 1989. This helps to execute the China National Plan for Disaster Reduction, the China Centre for Disaster Reduction and many relevant projects and programmes.

2. India

In India, response measured appeared significantly after this country was hit by 1997 Bhuj earthquake. After the 1995 Bhuj earthquake The Indian government has established a network of seismic stations to monitor the seismiscity of the country and has enacted and revised building codes.

3. Japan

According to IDNDR-ESCAP (1999), the Disaster Countermeasures Act and the Large-scale Earthquake Countermeasures Act designate are responsible for disaster prevention at national and local levels in Japan. The Disaster Prevention Research Institute of Kyoto University is conducting research on the prevention and reduction of natural disasters. The National Land Agency has jurisdiction over the Act on Special Measures for Active volcanoes, and has been responsible for the planning and underlying policies of the Volcanic Disaster Countermeasures. Among the precautionary measures taken are the improvements of roads and port facilities for rapid evacuation in case of an imminent volcanic disaster. Shelters against ash fall and volcanic bombs have been built, communication networks improved and evacuation drills are being conducted. The geophysical observation systems are being tested regularly, and as a result volcanic eruption predictions are being made using tilt meters, the measuring equipment for extension/contraction, magnetometry as well as optical camera. The Usu Volcano eruption prediction was made successfully in 2000 with the help of historical documents and eruption materials on record. The hazard map was used for evacuating 16,000 residents from the danger zone. No causality was reported but 200 families lost their homes. A revised hazard map of the area was published in 2002 (see Tadahide Ui 2004).

The NHK news dated 23rd August 2004 says that the Government panel in Japan gives quake ratio for south Kanto. According to the NHK news, Tokyo and its vicinity have a 70 % probability of having an earthquake with a magnitude of around seven within the next 30 years. Tokyo and its four adjacent prefectures have experienced five magnitude-seven quakes in total in the past 120 years, or one every 24 years on average. Experts say the ocean plate moving under the continental plate causes such tremors, creating tectonic pressure under the area. But the panel also says the probability in the next 30 years of a magnitude-eight quake, like the Great Kanto Earthquake 81 years ago, is only 0.8 %. It has been noted that these quakes have occurred only once in 200 to 400 years. Professor Kunihiko Shimazaki of Tokyo University's Earthquake Research Institute says the study does not include quakes directly above an epicenter less than 30 km underground. He said if such quakes were included, the probability would rise, and called for anti-quake measures without delay.

4. Pakistan

In Pakistan, awareness about earthquake hazards is very poor (Khan et al., 2001). According to Khan et al. (2002), the population of Pakistan has grown at alarming rates, and this increase has been coupled with migration of the people to cities, thus, causing fast but uncontrolled growth of urban areas. They further said that the building codes are either inappropriate or non-existing, and even if such building codes exist, their implementations are not according to the standard devised parameters. Moreover, there is hardly any disaster management programme at public or government level. Above all there is drastic lack of scientific data about the potential seismic hazards in the Pakistan (Khan et al., 2002).

5. Turkey

The Government of Turkey has launched a campaign to aware the general public though media showing proper construction methods for self-builders in rural areas (IDNDR-ESCAP 1999). The General Directorate of Disaster Affairs has successfully lobbied the media to repeat the message that natural disaster loss in Turkey is largely avoidable. Among the regional cooperative activities on natural disaster preparedness and loss reduction in which the country is involved, is the Cooperative Programme for Seismic Risk Reduction in the Mediterranean Region (SEISMED).

VI. Response required to the earthquake disasters

In order to develop the appropriate systems and measures to mitigate the effects of natural hazards, it must first be studied how such hazards become disasters (IDNDR-ESCAP 1999). Susceptibility of an area to a natural hazard or the probability of its occurrence defines the possible risk of exposure to a natural hazard at that place. A natural phenomenon is considered to be a natral disaster only when it causes both loss of life and considerable damage to property. For example, if some very strong earthquakes hit areas far from human centres, it just becomes scientific information. However, even a relatively mild earthquake, such as the Kobe earthquake, causes a disaster at extreme level.

The Asia and Pacific region have experienced devastations of increasing scale from earthquake disasters in the recent years. By comparing the scale of hazards vis-à-vis their consequences in the region, it can be found in most of the cases that the relative magnitude of damage to lives and property by far outstrips that of the natural hazard itself (IDNDR-ESCAP 1999). The human beings by themselves amplify the level of destruction and thereby transform events of natural hazards into disasters. The following paragraphs describe how the effects of natural hazards are amplified and act as the main factors of natural disasters in the region.

Rapid population growth in the region is one of the main elements that increase vulnerability to natural hazards causing natural disasters. In the first place, the higher rate of population growth directly results in high population density and higher level of physical infrastructure. High population densities almost inevitably result in high death tolls, and high property loss. In some areas with a high population concentration, even in the case of early warning of a natural hazard, preventive service measures cannot reach everybody. Consequently, a large section of people are left to face the hazards with their own means. Places of higher concentrations of physical infrastructure without adequate safeguards are very vulnerable to damage and the situation can become even more complicated as it is not easy to quickly rehabilitate such facilities (IDNDR-ESCAP 1999).

Ⅶ. Summary and conclusions

Earthquakes are the most destructive natural disasters. Around the world, seismic activity has killed millions of people and nearly 75% of these fatalities are reported from Asia and the Pacific region.

The densely populated areas with poor building structures is the main cause of earthquake disaster. As the increase in population growth and the haphazard enlargement of urban areas amplify earthquake disaster, therefore, an appropriate system is required to deal with this problem. The long-term planning by collecting all available earthquake data of the region can identify the hazard-free areas to be suitable for industrial and urban development. Moreover, to avoid a disaster, the disaster-prone areas must be analyzed for the past disaster events and major structures of public concern. Risk assessment and hazard mapping must be prepared that could delineate areas vulnerable to earthquake disasters. And building codes must be prepared and revised regularly.

There is a general need to establish or strengthen the institutional frameworks for natural disaster preparedness and reduction at central, regional, district, and community levels. Last but not least, earthquakes are natural calamities, which cannot be stopped, however, by taking appropriate measures, the damage to be inflected by earthquakes can be reduced significantly.

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